ISSN (print) 0093-4666 © 2011. Mycotaxon, Ltd. ISSN (online) 2154-8889

MYCOTAXON

http://dx.doi.org/10.5248/117.405

Volume 117, pp. 405–422 *July–September 2011*

The genus *Cladonia* (lichenized *Ascomycota, Cladoniaceae*) in South Korea

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Abstract — During a comprehensive study of *Cladonia* from South Korea, 41 taxa were recognized, including *C. dehiscens*, *C. floerkeana*, *C. macroptera,* and *C. rappii* var. *exilior*, new to South Korea. Brief information and discussion are provided for each taxon, together with a key to the taxa recorded from South Korea.

Key words — lichen-forming fungus, taxonomy, new records

Introduction

Cladonia is one of most common lichen genera, widely distributed on all continents and including more than 400 species worldwide (Ahti 2000). Park (1990) was the first to conduct an expert study of lichens in South Korea. Her 'Macrolichen flora of South Korea,' however, included only 22 *Cladonia* species, and the omission of many species we have since collected has made identification difficult. Thus, we began comprehensive research on the genus in South Korea with extensive field surveys from 2003 to 2010 and found several *Cladonia* species previously not known in this country. Here we provide information for 41 *Cladonia* taxa and a key to the South Korean species. Here we follow the taxonomic system set forth by Ahti (2000), separating South Korean *Cladonia* into five sections based on the secondary metabolites as identified by High Performance Liquid Chromatography (HPLC): *Cladonia*, *Cocciferae, Helopodium*, *Perviae,* and *Unciales. Cladina* is treated as a subgenus of *Cladonia*.

Material and methods

We examined 496 *Cladonia* specimens collected during 2003–2010 in South Korea, and deposited in the Korean Lichen Research Institute (KoLRI), Sunchon National University. External morphological descriptions were based on air-dried material, and

all specimens were observed under a Nikon SMZ645 stereomicroscope. The chemical characters were determined by color reaction according to Yoshimura (1974): K (10% aqueous KOH solution), C (saturated aqueous NaOCl solution), KC (10% KOH followed by C solution), P (5% alcoholic solution of para-phenylenediamine). Chemical compounds were identified using Thin Layer Chromatography (Culberson 1972; Elix et al. 1987; Orange et al. 2001; White & James 1985).

Taxonomy

Key to the sections of *Cladonia*

1. Podetia ecorticate, surface dull and webby ..... A. Subg. ***Cladina***
1. Podetia corticate **2**
2. Apothecia and pycnidia red ..... B. Sect. ***Cocciferae***
2. Apothecia and pycnidia brown **3**
3. Podetia yellowish and smooth, containing usnic acid ..... C. Sect. ***Unciales***
3. Podetia green, gray or brown, not yellowish, without usnic acid (except in *C. bacilliformis*) **4**
4. Basal squamules well developed and large, podetia small or sometimes evanescent, without cups ..... D. Sect. ***Helopodium***
4. Basal squamules usually persistent, podetia usually with well developed cups, axils and cup center closed ..... F. Sect. ***Cladonia***
4. Basal squamules evanescent, podetia branched, without cups, axils open and the cup center perforate ..... E. Sect. ***Perviae***

Key to the *Cladonia* taxa recorded from South Korea

A. *Cladonia* subg. *Cladina*

1. Podetia gray, KC–, lacking usnic acid **2**
1. Podetia yellowish, KC+ yellow, containing usnic acid ..... 2. ***C. arbuscula* subsp. *beringiana***
2. Ultimate branches pointing in one direction, polychotomously branched, final branchlets 2–4 ..... 32. ***C. rangiferina* subsp. *rangiferina***
2. Podetia small and slim, dichotomously branched, final branchlets 2 ..... 33. ***C. rangiferina* subsp. *grisea***

B. *Cladonia* sect. *Cocciferae*

1. Podetia usually topped with cups **2**
1. Podetia without cups **5**
2. Podetia sorediate ..... 29. ***C. pleurota***
2. Podetia esorediate, with granules or squamules **3**
3. Podetia usually covered with granules, containing squamatic acid .. 19. ***C. granulans***
3. Podetia covered with squamules or scaly plates **4**

4. Podetia covered with squamules, containing didymic acid. . . . .24. ***C. metacorallifera***
4. Podetia covered with scaly plates, containing zeorin. . . . . 6. ***C. coccifera***

5. Podetia distinctly corticate, sorediate. . . . . .14. ***C. floerkeana***
5. Podetia mostly ecorticate **6**

6. Farinose soredia throughout the podetia, corticate only at the basal parts, usually without squamules . . . . . 22. ***C. macilenta***
6. Podetia entirely decorticated, granulose soredia mixed with squamules . . . . . 11. ***C. didyma***

C. *Cladonia* sect. *Unciales*

Podetia bifurcating or forming small cups at apices, containing barbatic acid . . . . . 1. ***C. amaurocraea***
Podetia pointed and richly branched, containing squamatic acid . . . . . 41. ***C. uncialis***

D. *Cladonia* sect. *Helopodium*

1. Primary thallus persist, podetia rare **2**
1. Podetia usually present, primary thallus small or evanescent **3**

2. Primary thallus grayish green, rather large and thick, K+ yellow . . . . . .39. ***C. symphycarpia***
2. Primary thallus yellowish green, small, K– . . . . . 4. ***C. caespiticia***

3. Podetia with squamules, P+ yellow, containing psoromic acid . . . . . .10. ***C. dehiscens***
3. Podetia verruculose on surface, P+ red, containing fumarprotocetraric acid . . . . . 27. ***C. peziziformis***

E. *Cladonia* sect. *Perviae*

1. Podetia coarsely sorediate on the tips . . . . . 36. ***C. scabriuscula***
1. Podetia esorediate **2**

2. Podetia K+ yellow, containing atranorin, primary thallus abundant 40. ***C. turgida***
2. Podetia K–, primary thallus evanescent. **3**

3. Podetia P+ red, containing fumarprotocetraric acid **4**
3. Podetia P–, containing squamatic acid. **6**

4. Podetia up to 10 cm long, with abundant squamules . . . . . .23. ***C. macroptera***
4. Podetia shorter and slim, with few squamules **5**

5. Podetia simply branched, usually without apothecia. . . . . 15. ***C. furcata* var. *furcata***
5. Podetia with cymose branches, usually topped with apothecia . . . . . .16. ***C. furcata* var. *racemosa***

6. Funnel-like cups present, with large perforation in the center, podetial surface smooth and lacking squamules. . . . . 9. ***C. crispata***
6. Squamules abundant on the podetia, narrow cups present or not. . . 37. ***C. squamosa***

F. *Cladonia* sect. *Cladonia*

1. Podetia yellowish green, containing usnic acid . . . . . 3. ***C. bacilliformis***
1. Podetia not yellowish, without usnic acid **2**

2. Podetia esorediate **3**
2. Podetia sorediate **12**

3. Podetia usually topped with cups **4**
3. Podetia without cups or with shallow cups **9**

4. Podetia proliferating from the center of the cups . . . . . 34. ***C. rappii*** **var.** ***exilior***
4. Proliferation absent or on the margin of the cups **5**

5. Podetia with distinct deep cups. **6**
5. Cups shallow, corticate inside of the cups **8**

6. Podetia P+ yellow, containing psoromic acid . . . . . 38. ***C. subconistea***
6. Podetia P+ red-brown, containing fumarprotocetraric acid. **7**

7. Cups small, K+ yellow, containing atranorin . . . . . 21. ***C. kurokawae***
7. Cups large, goblet shaped, scaly plated inside of the cups, K–, without atranorin . . . . . 30. ***C. pyxidata***

8. Cups regular, apothecia large, base of the podetia not blackened . . . . . 18. ***C. gracilis*** **subsp.** ***turbinata***
8. Cups irregular, base of the podetia blackened, with white areolae . . . 28. ***C. phyllophora***

9. Podetia with smooth and continuous cortex, with areolae **10**
9. Podetia lacking continuous cortex, largely decorticated **11**

10. Podetia with abundant squamules, usually pointed at apices . . . . . 12. ***C. fenestralis***
10. Podetia with few squamules, topped with small shallow cups . . . . . 17. ***C. gracilis*** **subsp.** ***gracilis***

11. Podetia pointed at apices, rarely branched, with few squamules, sometimes small and granule-like . . . . . 32. ***C. ramulosa***
11. Podetia with many squamules on the lower parts, small cups present on the tips, apothecia large . . . . . 26. ***C. mongolica***

12. Podetia pointed or with tiny cups at apices **13**
12. Podetia with obvious cups **15**

13. Podetia corticate only at the base, with farinose soredia throughout . . . . . 7. ***C. coniocraea***
13. Podetia corticate, with patches of soralia. **14**

14. Primary thallus esorediate, podetia up to 4 cm tall, with soralia on upper parts of the podetia. . . . . 8. ***C. cornuta*** **subsp.** ***cornuta***
14. Primary thallus sorediate, podetia short, with patches of farinose soredia . . . . . 26. ***C. ochrochlora***

15. Cups shallow, margin irregular and asymmetrical. . . . . 34. ***C. rei***
15. Cups deep, margin entire and even **16**

16. Soredia granulose, cups large and broad . . . . . 5. ***C. chlorophaea***
16. Soredia farinose. **17**

17. Podetia short, cups small, K+ yellow, containing atranorin . . . . . 20. ***C. humilis***
17. Podetia covered with farinose soredia, K–, without atranorin . . . . . 13. ***C. fimbriata***

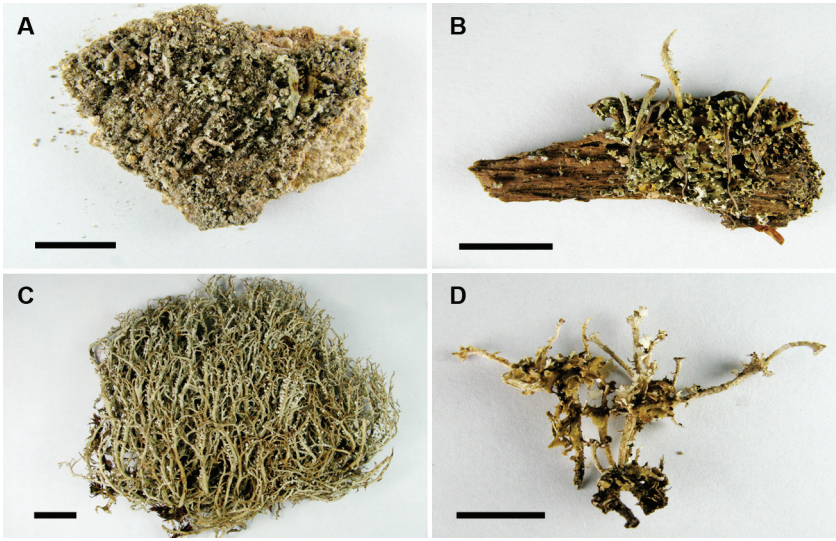

Figure 1: A. *Cladonia dehiscens*; B. *C. floerkeana*; C. *C. macroptera*; D. *C. rappii* var. *exilior*. Scale bars: A, B, D = 1 cm; C = 2 cm.

1. *Cladonia amaurocraea* (Flörke) Schaer.

Remarks — This species is characterized by its yellowish podetia, frequently tipped with small cups. *Cladonia uncialis* resembles this species, but it does not have cups, and it contains squamatic acid but not barbatic acid. *C. arbuscula* is also yellowish with usnic acid, but its podetia lack a cortex.

This species is reported from Japan, North America and Europe (Thomson 1984; Yoshimura 1974). In South Korea, common, usually on rock, mostly found in the northern part and over the altitude of 800 m.

Representative specimens (of 15) examined — **SOUTH KOREA. Gangwon Prov.**, Taebaek city, Mt. Naejang, 35°29′47.2″N 126°53′44.5″E, alt. 1080 m, Hur 030419; Mt. Sorak, 38°07′14.5″N 128°23′03.5″E, alt. 1355 m, Hur 041490; **Gyeongbuk Prov.**, Mungyeong city, Mt. Juhul, 36°46′58.5″N 128°05′21.3″E, Hur 040160; **Gyeongnam Prov.**, Mt. Gaya, 35°49′11.3″N 128°07′18.2″E, alt. 1440 m, Hur 040215.

2. *Cladonia arbuscula* subsp. ***beringiana*** Ahti

Remarks — The subspecies is resembles *C. rangiferina* but with yellowish podetia due to the presence of usnic acid. A worldwide complex with many subspecies and chemotypes, *C. arbuscula* is usually represented by *C. arbuscula* subsp. *beringiana* (Ahti 2000) in eastern Asia and (in Japan) subsp. *mitis* (Yoshimura 1974, Harada et al. 2004).

This subspecies is reported from North America, Europe, Japan and China (Harada et al. 2004; Thomson 1984; Wei 1991). In South Korea, only one specimen was found on soil during our study.

Specimen examined — **SOUTH KOREA**. **Gyeongbuk Prov.**, Mt. Juwang, 36°23′47.7″N 129°08′50.5″E, alt. 270 m, Hur 050584.

3. *Cladonia bacilliformis* (Nyl.) Vain.

Remarks — Characterized by having soredia all over the podetia, this species might be confused with the sorediate species *C. ochrochlora* and *C. coniocraea* but differs in having yellowish podetia and containing usnic acid as the main compound.

Cladonia bacilliformis is also known from North America and China (Thomson 1984; Wei 1991). In South Korea, very rare, found only in some low altitude mountains growing on soil or rock.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Ilrim, 34°40′43.2″N 127°00′41.8″E, alt. 360 m, Hur 050375. Mt. Cheongwan, 34°32′39.8″N 126°56′51.5″E, alt. 200 m, Hur 050527. **Gyeonggi Prov.**, Mt. Gakhul, 38°06′55.1″ N 127°22′49.6″ E, alt. alt. 826 m, Hur 080336.

4. *Cladonia caespiticia* (Pers.) Flörke

Remarks — Diagnosed by very short (≤ 0.5 cm) podetia and pycnidia on the primary thallus, *C. caespiticia* might be confused with *C. symphycarpia* but lacks norstictic acid and has a smaller thinner primary thallus.

Also known from North America, Europe, South Africa, and Asia (Park 1990); not common or widespread in South Korea, where it grows on soil or rock at altitudes below 900 m.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Baekun, 35°04′17.4″N 127°39′27.1″E, alt. 840 m, Hur 041268. **Gangwon Prov.**, Mt. Sorak, 38°10′46.7″N 128°21′54.7″E, alt. 430 m, Hur 041536. **Chungnam Prov.**, Mt. Gaeryeong, 36°21′30.7″N 127°12′44.5″E, alt. 750 m, Hur 041620.

5. ***Cladonia chlorophaea*** (Flörke ex Sommerf.) Spreng.

Remarks — Characterized by wide-open cups and granulose soredia, *C. chlorphaea* could be confused with *C. grayi,* which differs in producing grayanic acid, and *C. pyxidata*, which has granular squamules but no soredia.

Widely distributed from the temperate zone to the Antarctic/Arctic (Ahti 2000), *C. chlorophaea* is rather common in South Korea, where it grows on exposed soil (or sometimes rock or moss) at altitudes above 1000 m.

Representative specimens (of 13) examined — **SOUTH KOREA**. **Jeju Prov.**, Mt. Halla, 33°05′48.8″N 126°55′11.6″E, alt. 1325 m, Hur 030371. **Gangwon Prov.**, Mt. Hambaek, 37°11′48.6″N 128°55′06.5″E, alt. 1194 m, Hur 030689. Mt. Odae, 37°47′55.3″N 128°32′53.3″E, alt. 1490 m, Hur 040472. **Jeonbuk Prov.**, Mt. Palgong, 35°36′01.8″N 127°27′57.4″E, alt. 688 m, Hur 050400.

6. *Cladonia coccifera* (L.) Willd.

Remarks — Characterized by large, red apothecia on the proliferation, surface squamules, and usnic acid and zeorin as the secondary metabolites, *C. coccifera* resembles *C. pleurota* but lacks soredia while *C. pleurota* has granulose soredia.

Circumpolar in the northern hemisphere south to the Himalayas (Stenroos 1989), *C. coccifera* is uncommon in South Korea where it is found on rock or soil at 15–1000 m or above.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Gohong county, Sorok Island, 35°48′11.2″N 129°18′47.3″E, alt. 15 m, Hur 030063-1. **Gangwon Prov.**, Mt. Gariwang, 37°24′05.0″N 128°32′39.5″E, alt. 937 m, Hur 080058, Hur 080065. Mt. Tuda, 37°26′36.8″N 128°59′35.3″E, alt. 761 m, Hur 080110. **Gyeongbuk Prov.**, Mt. Joryeong, 37°48′27″N 128°03′32″E, alt. 500 m, Hur 080303.

7. *Cladonia coniocraea* (Flörke) Spreng.

Remarks — This species may be confused with *C. ochrochlora* but has extensively spreading farinose soredia over podetia rather than round soralia. It is mostly decorticated, while *C. ochrochlora* has a well-developed cortex all over the podetia.

Known from the northern hemisphere and Australia (Park 1990), *C. conciocraea* is uncommon in South Korea where it is found on rock or moss.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Naejang, 35°29′47.2″N 126°53′44.5″E, alt. 1080 m, Hur 030423. Mt. Sorak, 38°06′40.4″N 128°24′26.8″E, alt. 1335 m, Hur 041452. **Jeju Prov.**, Jeju Island, 33°24′26.6″N 126°29′46.0″E, alt. 600 m, Hur 040634-1.

8. *Cladonia cornuta* (L.) Hoffm. subsp. ***cornuta***

Remarks — Very close to *C. coniocraea*, which is corticate only at the base, this subspecies has a more extensive cortex and patches of soralia. *Cladonia ochrochlora* is also similar, but it is short and stout, its podetia are usually topped with small cups, and the primary thallus has soredia, while *C. cornuta* subsp. *cornuta* lacks cups, is slim and tall, and has an esorediate primary thallus.

Circumpolar, boreal, arctic, and in the southern hemisphere (Thomson 1984), the subspecies is rather common throughout South Korea, usually growing on soil, sometimes on wood or rock.

Representative specimens (of 22) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Jiri, 35°18′39.4″N 127°35′54.3″E, alt. 1620 m, Hur 040294. **Jeju Prov.**, Jeju Island, 33°21′30.4″N 126°31′19.3″E, alt. 1710 m, Hur 040740. **Jeonbuk Prov.**, Mt. Naejang, 35°29′46.1″N 126°53′56.7″E, alt. 600 m, Hur 050021. **Gangwon Prov.**, Mt. Sorak, 38°08′53.5″N 128°20′05.3″E, alt. 1080 m, Hur 050279.

9. *Cladoonia crispata* (Ach.) Flot.

Remarks — The funnel-like cups make this species quite unique. *Cladonia crispata* occurs on soil and may be confused with *C. furcata*, which, however,

does not form cups and the tips and contains fumarprotocetraric acid but not squamatic acid.

Circumpolar, arctic, temperate, it is also found in South America (Thomson 1984), *C. crispata* is very rare in South Korea, where it usually grows on soil or thin soil over rock at altitudes c. 1000 m.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Baekun, 35°10′ N 127°60′ E, alt. 1045 m, Hur 030291. **Gangwon Prov.**, Mt. Taebaek, 37°06′15.5″ N 128°56′06.2″ E, alt. 1000 m, Hur 030391, Hur 030394.

10. ***Cladonia dehiscens*** Vain. Fig. 1A

Remarks — New to South Korea, *C. dehiscens* may be confused with *C. peziziformis*, but it contains psoromic acid only, the podetia surfaces are partly decorticated and squamulose; *C. peziziformis* contains atranorin, and the surface is verruculose without squamules.

Previously known only from China (Wei 1991), the species is rather rare in South Korea, where it was found only found at c. 250 m on Mt. Gumsan (Gyeongnam province), growing on rock.

Specimens examined — **SOUTH KOREA**. **Gyeongnam Prov.**, Namhae county, Mt. Gumsan, 34°45′38.5″N 128°02′55.5″E, alt. 249 m, Hur 070944, Hur 070945.

11. *Cladonia didyma* (Fée) Vain.

Remarks — In having red apothecia and soredia, *C. didyma* is resembles *C. macilenta*. The latter species, however, has thamnolic acid as the main chemical compound and usually farinose soredia all over the podetia, while *C. didyma* has didymic acid and the granulose soredia mix with squamules.

Pantropical, extending to warm temperate areas (Ahti 2000). In South Korea, only one specimen was found on bark from the Jeju Island.

Specimen examined — **SOUTH KOREA**. **Jeju Prov.**, Jeju Island, 33°26′04.4″N 126°34′01.7″E, alt. 545 m, Hur 040878.

12. ***Cladonia fenestralis*** Nuno

Remarks — This species might be confused with *C. gracilis*, but *C. fenestralis* has many more squamules on the podetia (which are usually taller) and inconspicuous cups. *Cladonia gracilis* has regular shallow cups on the tips of the podetia.

This species has been reported from Southeast Asia (Sipman 1993) and South Korea (Hur et al. 2005). During our study, only two specimens were found growing on rocks from Jeonbuk and Gangwon provinces.

Specimens examined — **SOUTH KOREA**. **Jeonbuk Prov.**, Mt. Seonun, 35°29′46.9″N 126°53′40.7″E, alt. 300 m, Hur 030240. **Gangwon Prov.**, Mt. Naejang, 35°29′47.2″N 126°53′44.5″E, alt. 1080 m, Hur 030421.

13. *Cladonia fimbriata* (L.) Fr.

Remarks — Characterized by slim podetia, narrow cups, and farinose soredia, *C. fimbriata* is closely resembles *C. chlorophaea*, which differs in wider cups and granulose soredia.

A common temperate to boreal and arctic-antarctic species (Ahti 2000), *C. fimbriata* is very rare in South Korea, found only in Chungbuk province, growing on rock.

Specimen examined — **SOUTH KOREA**. **Chungbuk Prov.**, Mt. Sobaek, 36°57′18″N 128°28′52.3″E, alt. 1389 m, Hur 030769.

14. *Cladonia floerkeana* (Fr.) Flörke Fig. 1B

Remarks — New to South Korea, *C. floerkeana* might be confused with another sorediate species *C. macilenta*, but the latter species has farinose soredia and the whole podetia are almost entirely decorticated, while *C. floerkeana* is corticate over most of the podetia, its soredia are granulose, and it has squamules on the podetia.

Also reported from North America, Europe, Australasia (Ahti 2000), and East Asia (Wei 1991), *C. floerkeana* is very rare in South Korea, where it was found growing on bark at c. 300 m on Mt. Juwang.

Specimen examined — **SOUTH KOREA**. **Gyeongbuk Prov.**, Mt. Juwang, 36°23′47.7″N 129°08′50.5″E, alt. 270 m, Hur 050587.

15. *Cladonia furcata* (Huds.) Schrad. var. ***furcata***

Remarks — This variety is easily recognizable by having a well-developed cortex, simple branches, and a few squamules. It has many variations and forms; some Korean specimens, which are rather long and stout (≤ 8 × 2 mm), would have been referred to *C. furcata* var. *pinnata* (Fink 1904), but this has recently been synonymised with *C. furcata* var. *furcata* (Hur et al. 2005).

A widespread warm to cold temperate species (Ahti 2000), *C. furcata* is the most common species in South Korea, widely distributed from low to high altitudes, usually growing on humus or soil over rock, under the shady forest.

Representative specimens (of 53) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Baekun, 35°10′ N 127°60′ E, alt. 1050 m, Hur 030289. **Gangwon Prov.**, Mt. Taebaek, 37°06′25.9″N 128°56′47.8″E, alt. 963 m, Hur 030633. **Chungbuk Prov.**, Mt. Sobaek, 36°57′17.6″N 128°28′47.1″E, alt. 1394 m, Hur 030778. **Gyeongbuk Prov.**, Mt. Juhul, 36°46′58.5″N 128°05′21.3″E, alt. 675 m, Hur 040157. **Chungnam Prov.**, Mt. Gaeryong, 36°21′25.6″N 127°12′35.3″E, alt. 770 m, Hur 041628.

16. *C. furcata* var. ***racemosa*** (Hoffm.) Flörke

Remarks — One additional variety of *C. furcata* has been found in Korean specimens, which differs from other species by the subradiate branching

towards the apex, the microsquamules on the surface, and the apothecia commonly present on the cymose branch tips. Thallus P + red, containing fumarprotocetraric acid.

Specimen examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Odae, 37°47′43.3″N 128°34′22.0″E, alt. 1240 m, Hur 040481.

17. *Cladonia gracilis* (L.) Willd. subsp. ***gracilis***

Remarks — Similar to *C. furcata*, *C. gracilis* subsp. *gracilis* is much more slender and has fewer squamules and podetia tips usually topped with cups. The similar *C. maxima* lacks a primary thallus and has much longer, unbranched podetia. The subspecies also differs from *C. cornuta* by lacking soredia.

Distributed from circumpolar regions to South America (Thomson 1984), this subspecies is rare in South Korea, usually found growing on rock at altitudes above 900 m.

Specimens examined — **SOUTH KOREA**. **Jeonbuk Prov.**, Mt. Naejang, 35°29′46.1″N 126°53′56.7″E, alt. 600 m, Hur 050020. **Jeju Prov.**, Mt. Halla, 33°21′53.8″N 126°30′40.3″E, alt. 1695 m, Hur 090207. **Gangwon Prov.**, Mt. Jobong, 37°56′10.7″N 128°33′74.7″E, alt. 980 m, Hur 090256.

18. *Cladonia gracilis* subsp. ***turbinata*** (Ach.) Ahti

Remarks — This subspecies differs from subsp. *gracilis* mainly by having large, wide cups and being covered with squamules. The similar *C. rappii* differs in proliferating from the center of the podetial cups. The also similar *C. phyllophora* differs in having regular cups and a smooth cortex.

Cosmopolitan (Ahti 1980), *C. gracilis* subsp. *turbinata* is very common and widespread in South Korea on soil or mosses over rock at altitudes above 1000 m.

Representative specimens (of 24) examined — **SOUTH KOREA**. **Jeju Prov.**, Mt. Halla, 33°05′48.8″N 126°55′11.6″E, alt. 1655 m, Hur 030361; alt. 800 m, Hur 030368. **Jeonnam Prov.**, Mt. Jiri, 35°19′09.4″N 127°41′15.9″E, alt. 1600 m, Hur 040348. **Gangwon Prov.**, Mt. Taebaek, 37°06′10.4″N 128°57′16.1″ E, alt. 1120 m, Hur 041021.

19. *Cladonia granulans* Vain.

Remarks — Characterized by slender podetia covered by squamules or granules on the podetia, *C. granulans* is quite similar to *C. metacorallifera* but lacks didymic acid and has no proliferation on the cup margins.

Originally described from Japan and also known from North America (Thomson 1984), this species is rare in South Korea and usually found at altitudes above 1000 m, growing on bark or soil.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Naejang, 35°29′47.2″N 126°53′44.5″E, alt. 1050 m, Hur 030418. **Jeju Prov.**, Jeju Island, 33°21′42.4″N 126°32′56.9″E, alt. 1670 m, Hur 040819. **Chungbuk Prov.**, Mt. Sobaek, 36°55′47.5″ N 128°27′22.9″ E, alt. 1301 m, Hur 070338.

20. *Cladonia humilis* (With.) J.R. Laundon

Remarks — *Cladonia humilis,* which contains atranorin, is difficult to differentiate from *C. chlorophaea*, which lacks atranorin and has larger podetia.

A widespread temperate species (Ahti 2000), *C. humilis* is uncommon in South Korea, where it is found on soil over rock at low altitudes.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Sorok Island, 35°48′11.2″N 129°18′47.3″E, alt. 60 m, Hur 030056. **Gyeongbuk Prov.**, Mt. Juhul, 36°46′58.5″N 128°05′21.3″E, alt. 657 m, Hur 040156; 36°46′46.0″N 128°06′02.1″E, alt. 845 m, Hur 040151. **Chungbuk Prov.**, Mt. Joryeong, 37°01′33.3″N 128°11′59.2″E, alt. 285 m, Hur 061110.

21. *Cladonia kurokawae* Ahti & S. Stenroos

Remarks — Characterized by small granules rather than real soredia, somewhat small podetia and cups, fumarprotocetraric acid, and atranorin, *C. kurokawae* resembles *C. subconistea*, which lacks fumarprotocetraric acid and contains psoromic acid as the main compound.

Originally described from East Asia (Lai 2000), *C. kurokawae* is rather common in South Korea where it is found mostly on soil or mossy rock in low altitude mountains.

Representative specimens (of 17) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Baekun, 36°57′14.5″N 128°29′18.8″E, alt. 1000 m, Hur 0300182-2. **Jeonbuk Prov.**, Mt. Naejang, 35°48′11.2″N 126°18′47.3″E, alt. 600 m, Hur 030453. **Gyeongnam Prov.**, Mt. Gumsan, 34°45′44.2″N 127°59′29.6″E, alt. 290 m, Hur 040031. **Gyeonggi Prov.**, Mt. Myeongji, 37°55′57.7″N 127°28′53.3″E, alt. 223 m, Hur 080669.

22. *Cladonia macilenta* Hoffm.

Remarks — This species is characterized by having red apothecia and farinose soredia all over the podetia. TLC detected two chemical races in Korean materials: (1) didymic and thamnolic acids; (2) didymic, barbatic, and usnic acids. The horizontal primary thallus generally contains only thamnolic acid (Asahina 1970).

Widespread worldwide (Ahti 2000), *C. macilenta* is also common and widespread in South Korea, where it usually grows on rotting wood, bark, humus, or soil at altitudes above 500 m.

Representative specimens (of 14) examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Hambaek, 37°11′48.6″N 128°55′06.5″E, alt. 1194 m, Hur 030685. Mt. Seokbyeong, 37°34′29.9″N 128°51′21.8″E, alt. 686 m, Hur 080188. **Jeju Prov.**, Jeju Island, 33°24′26.6″N 126°29′46.0″E, alt. 600 m, Hur 040634. **Jeonnam Prov.**, Wando Island, 34°21′10.3″N 126°41′10.9″E, alt. 535 m, Hur 050142.

23. *Cladonia macroptera* Räsänen Fig. 1C

Remarks — Characterized by long (≤ 10 cm) podetia, *C. macroptera* differs from *C. furcata* by tall thick podetia with rare branches and densely squamulose

and an areolate cortex that differs from the more or less continuous cortex in *C. furcata*.

Previously known only from China and Canada (Brodo et al. 1987, Wei 1991), *C. macroptera* is new to South Korea where two specimens were found growing on moss over rock.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Duryon, 37°06′27.6″N 128°56′48.8″E, alt. 200 m, Hur 030314. **Gangwon Prov.**, Mt. Odae, 37°47′36.2″N 128°34′37.0″E, alt. 1195 m, Hur 040483.

24. *Cladonia metacorallifera* Asahina

Remarks — This species is characterized by having cups topped with red apothecia, without soredia but squamulose and contains squamatic acid. It may be confused with *C. coccifera*, but the latter species usually has farinose granules resembling soredia inside of the cups and contains zeorin.

Also known from North America, Japan, and China (Thomson 1984; Wei 1991), *C. metacorallifera* is uncommon in South Korea where it usually grows on soil over rock at 1000–1700 m altitudes.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Naejang, 35°29′47.2″N 126°53′44.5″E, alt. 1080 m, Hur 030420. Mt. Sorak, 38°06′42.8″N 128°24′21.8″E, alt. 1360 m, Hur 041466. **Jeju Prov.**, Jeju Island, 33°21′32.9″N 126°31′54.9″E, alt. 1920 m, Hur 040758. **Jeonnam Prov.**, Mt. Jiri, 35°19′40.9″N 127°44′15.0″E, alt. 1564 m, Hur 060686; 35°18′59.5″N 127°42′26.1″E, alt. 1659 m, Hur 060955.

25. *Cladonia mongolica* Ahti

Remarks — Characterized by dense squamules on the lower podetia and usually with large apothecia, *C. mongolica* resembles *C. scabriuscula* but lacks soredia near the podetia tips.

Also reported from China (Wei 1991), the species is rather rare in South Korea and grows on soil or rock. Kwang-Hee Moon reported *C. mongolica* from Mt. Sorak (Moon 1999), while we have found more specimens from different localities in the country.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Duryon, 37°06′27.6″N 128°56′48.8″E, alt. 200 m, Hur 030318. **Gangwon Prov.**, Mt. Hambaek, 37°11′48.6″N 128°55′06.5″E, alt. 1194 m, Hur 030686. **Chungbuk Prov.**, Mt. Sobaek, 36°57′27.0″N 128°26′40.7″E, alt. 618 m, Hur 030711.

26. *Cladonia ochrochlora* Flörke

Remarks — Characterized by farinose soredia, this species might be confused with *C. coniocraea*, which differs by being sorediate all over the podetia while *C. ochrochlora* has continuous cortex. It is also similar to the yellowish *C. bacilliformis* but lacks usnic acid so the thallus color is greener.

Mainly distributed in temperate and boreal areas (Ahti 2000), *C. ochrochlora* is not very common in South Korea, where it occurs mostly in the northern part at altitudes above 1000 m.

Specimens examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Jiri, 35°18′07.4″N 127°34′00.1″E, alt. 1440 m, Hur 060266. **Jeonbuk Prov.**, Mt. Deogyu, 35°51′05.3″N 127°44′55.4″E, alt. 1576 m, Hur 060506. **Gangwon Prov.**, Mt. Taebaek, 37°05′46.1″N 128°55′05.6″E, alt. 1572 m, Hur 070633. Mt. Gariwang, 37°24′05.0″N 128°32′39.5″E, alt. 937 m, Hur 080026, Hur 080029.

27. *Cladonia peziziformis* (With.) J.R. Laundon

Remarks — Reported previously from South Korea (Wang et al. 2008), *C. peziziformis* is characterized by short verruculose podetia and roundish primary squamules. It is very similar to *C. cariosa*, which, however, contains atranorin. It also resembles *C. subcariosa*, which has significantly elongated primary squamules.

Primarily a temperate species that prefers mineral soil, *C. peziziformis* is common in the eastern United States, Europe, Japan, and China (Ahti 2000). In South Korea, only one specimen from Jeonnam province was found, growing on soil.

Specimen examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Baeka, 35°09′08.3″N 127°09′45.2″E, alt. 550 m, Bae 080032.

28. *Cladonia phyllophora* Ehrh. ex Hoffm.

Remarks — Characterized by whitish spots near the basal parts and quite similar to *C. gracilis* subsp. *turbinata, C. phyllophora* has more irregular cups, a decorticated area under the cups, and a base that usually blackens.

Distributed in circumpolar, boreal, and low arctic regions (Thomson 1984), *C. phyllophora* is common in South Korea, usually on soil over rock at altitudes above 1000 m,.

Representative specimens (of 10) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Jiri, 35°20′05.0″N 127°42′49.4″E, alt. 1525 m, Hur 040394. **Gangwon Prov.**, Mt. Hambaek, 37°11′48.6″N 128°55′06.5″E, alt. 1194 m, Hur 030687. Mt. Sorak, 38°09′17.4″N, E128°26′25.6″E, alt. 1255 m, Hur 050300.

29. *Cladonia pleurota* (Flörke) Schaer.

Remarks — Characterized by cups bearing granulose soredia, *C. pleurota* may be mistaken for *C. carneola* when the pycnidia are brownish but differs in having zeorin and isousnic acid.

Circumpolar in the arctic and the boreal forest (Thomson 1984), *C. pleurota* is not common in South Korea and is restricted to the northeastern part, usually on rock, soil, and at the base of the trees.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Gariwang, 37°24′05.0″N 128°32′39.5″E, alt. 937 m, Hur 080057. Mt. Taebaek, 37°12′35.7″N 128°55′13.0″E, alt. 1400 m, Hur 080297. **Gyeongbuk Prov.**, Mt. Joryeong 37°48′27″N 128°03′32″E, alt. 500 m, Hur 080304.

30. ***Cladonia pyxidata*** (L.) Hoffm.

Remarks — Characterized by bell-shaped cups covered inside and out by round squamules, *C. pyxidata* it may be confused with *C. chlorophaea*, which differs in usually wider and goblet shaped cups (that are sometimes narrow when young) that have granulose soredia inside the cups.

This is a cosmopolitan species (Thomson 1984). In South Korea, it is not widespread, growing on rock or soil, at the elevation lower than 1000 m.

Specimens examined — **SOUTH KOREA**. **Chungbuk Prov.**, Mt. Worak, 36°51′36.6″N 128°05′27.4″E, alt. 245 m, Hur 041158. **Gangwon Prov.**, Mt. Sorak, 38°08′53.5″N 128°20′05.3″E, alt. 1000 m, Hur 050275. **Jeonnam Prov.**, Mt. Dalma, 34°22′45.2″N 126°35′11.6″E, alt. 456 m, Hur 050344.

31. ***Cladonia ramulosa*** (With.) J.R. Laundon

Remarks — The species is characterized by squamules on the lower part of the podetia and partly decorticated. Morphologically, *C. rei* is very similar, but *C. ramulosa* lacks powdery soredia on the upper podetia and has translucent decorticated areas on the podetia. *Cladonia scabriuscula,* which might be confused with *C. ramulosa,* lacks homosekikaic acid.

A widespread temperate to tropical species (Ahti 2000), it is rather common in South Korea, usually on soil or rock and found at altitudes from sea level to above 1000 m.

Representative specimens (of 26) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Sorok Island, 35°48′11.2″N 129°18′47.3″E, alt. 60 m, Hur 030058. **Gangwon Prov.**, Mt. Taebaek, 37°06′15.5″N 128°56′06.2″E, alt. 1000 m, Hur 030392. Mt. Odae, 37°47′43.3″N 128°34′22.0″E, alt. 1240 m, Hur 040480. **Jeju Prov.**, Jeju Island, 33°34′00.1″N 126°45′44.4″E, alt. 10 m, Hur 090031.

32. ***Cladonia rangiferina*** (L.) Weber ex F.H. Wigg. subsp. ***rangiferina***

Remarks — The subspecies is easily recognizable by having grayish and webby podetial surface, with branches curved and facing a same direction. It is very similar to *C. rangiferina* subsp. *grisea,* but the branchlets of the latter subspecies are mainly isotomic dichotomously branched, and the podetium is thinner and smaller.

Circumpolar arctic to temperate in distribution (Thomson 1984), it is rather common over rock or soil in South Korea at altitudes above 1000 m.

Representative specimens (of 30) examined — **SOUTH KOREA**. **Jeju Prov.**, Mt. Halla, 33°57′32.6″N 126°29′17.5″E, alt. 1980 m, Hur 030357. **Gyeongbuk Prov.**, Cheongryangsa Temple, 36°47′25.2″N 128°55′25.4″E, alt. 885 m, Hur 040102. **Jeonnam Prov.**, Mt. Jiri, 35°19′03.9″N 127°41′22.7″E, alt. 1660 m, Hur 040352. Gangwon Prov., Mt. Gariwang, 37°24′05.0″N 128°32′39.5″E, alt. 937 m, Hur 080059.

33. *Cladonia rangiferina* subsp. ***grisea*** Ahti

Remarks — See under *C. rangiferina* subsp. *rangiferina*.

The subspecies is fairly common on Japanese mountains and also known from Korea, Taiwan and China (Ahti 1961). In South Korea, common and usually growing on rock under the open canopy.

Representative specimens (of 8) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Wolchul, 34°45′29.5″N 126°40′46.5″E, alt. 400 m, Hur 030115. **Jeju Prov.**, Jeju Island, 33°21′37.7″N 126°32′40.3″E, alt. 1755 m, Hur 040838. **Gangwon Prov.**, Mt. Sorak, 38°06′40.1″N 128°24′33.9″E, alt. 1335 m, Hur 041437. **Gyeongbuk Prov.**, Mt. Juwang, 36°23′47.7″N 129°08′50.5″E, alt. 270 m, Hur 050590.

34. *Cladonia rappii* var. ***exilior*** (Abbayes) Ahti Fig. 1 D

Remarks — A new record for South Korea, this variety is characterized by proliferating podetia and podetia cups that are usually very small. It is similar to *C. cervicornis,* which has 4–6 proliferation tiers compared to the 2–3 tiers usual for this variety.

Cladonia rappii is distributed in North America, Asia, Africa, and Melanesia (Ahti 2000). In South Korea, only this variety is found and mainly occurs in the southwestern part of Korea, usually growing on rocks.

Specimens examined — **SOUTH KOREA**. **Chungbuk Prov.**, Mt. Sobaek, 36°57′05.5″N 128°29′27.4″E, alt. 1375 m, Hur 030758. Mt. Joryeong, 36°49′00.9″N 128°02′53.7″E, alt. 784 m, Hur 061048. **Jeonnam Prov.**, Mt. Jiri, 35°15′59.2″N 127°34′40.7″E, alt. 530 m, Hur 040231; 35°19′54.5″N 127°43′04.7″E, alt. 1657 m, Hur 060701. **Gyeongnam Prov.**, Mt. Gaya, 35°48′36.9″N 128°08′20.9″E, alt. 746 m, Hur 060103.

35. *Cladonia rei* Schaer.

Remarks — Characterized by largely decorticated podetia with small cups and coarse soredia, *C. rei* resembles *C. gracilis* subsp. *gracilis,* except for the presence of the soredia, and homosekikaic acid. It could be confused with *C. scabriuscula,* which lacks cups on the apex and homosekikaic acid and has squamulose podetia.

This is a cosmopolitan species (Galloway 2007). In South Korea, it is rather rare and grows on soil or rock at altitudes below 1000 m.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Taebaek, 37°06′28.4″N 128°56′47.8″E, alt. 944 m, Hur 030626. **Jeonnam Prov.**, Mt. Baeka, 34°32′33.1″N 126°55′46.7″E, alt. 334 m, Hur 050556.

36. *Cladonia scabriuscula* (Delise) Leight.

Remarks — Characterized by dichotomously branched podetia and having granulose soredia at the apex, *C. scabriuscula* may be confused with *C. squamosa*, except for the different chemical compounds and absence of squamatic acid. It also resembles *C. furcata,* which differs in having a continuous cortex and lacking soredia on the podetia.

Widespread worldwide in primarily temperate, oceanic regions (Ahti 2000), *C. scabriuscula* is rather common and widespread throughout South Korea, usually on rock or soil over rock.

Representative specimens (of 33) examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Odae, 37°47′43.3″N 128°34′22.0″E, alt. 1240 m, Hur 040482. **Jeonbuk Prov.**, Mt. Deogyu, 35°52′13.5″N 127°46′42.3″E, alt. 830 m, Hur 050061. **Jeonnam Prov.**, Mt. Hulseok, 34°41′21.4″N 126°40′51.4″E, alt. 203 m, Hur 050476.

37. *Cladonia squamosa* (Scop.) Hoffm.

Remarks — This species is hard to identify when the squamules are greatly reduced and appear to be granular or even soredia; key characters are possession of squamatic acid and the lack of real soredia.

Widespread in temperate and colder regions in both northern and southern hemispheres (Ahti 2000), *C. squamosa* is common but not widespread in South Korea on soil or rock, sometimes at the base of a tree.

Representative specimens (of 9) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Wolchul, 36°56′50.5″N 128°29′51.2″E, alt. 400 m, Hur 030137. **Chungbuk Prov.**, Mt. Sobaek, 36°57′11.2″N 128°28′37.2″E, alt. 1404 m, Hur 030792. **Gangwon Prov.**, Mt. Sorak, 38°06′43.0″N 128°24′21.3″E, alt. 1375 m, Hur 041470.

38. ***Cladonia subconistea*** Asahina

Remarks — Diagnosed by psoromic acid, *C. subconistea* resembles *C. humilis* in having small podetia and cups but lacks the soredia and fumarprotocetraric acid found in the latter.

Known only from east Asia (Harada et al. 2004, Hur et al. 2005, Wei 1991), *C. subconistea* is very rare in South Korea, where it is found growing on rock, usually at altitudes below 500 m.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Chiak, 37°17′43.6″N 128°01′20.1″E, alt. 515 m, Hur 040562. **Gyeongnam Prov.**, Mt. Cheondae, 36°09′16.0″N 127°37′19.1″E, alt. 196 m, Hur 061145.

39. *Cladonia symphycarpia* (Flörke) Fr.

Remarks — Characterized by its short podetia (< 1 cm) and containing norstictic acid, *C. symphycarpia* (frequently misspelled as '*symphycarpa,*' see Ahti 2000) usually lacks podetia, so that it must be recognized based on the primary thallus alone.

Widespread in Eurasia and northern North America (Ahti 2000), the species is rather rare in South Korea and is restricted to the Sorak Mountains, growing on soil over rock.

Specimens examined — **SOUTH KOREA**. **Gangwon Prov.**, Mt. Sorak, 38°07′37.6″N 128°27′48.5″E, alt. 1300 m, Hur 041581; 38°09′37.7″N 128°19′26.5″E, alt. 660 m, Hur 050256, Hur 050260.

40. *Cladonia turgida* Hoffm.

Remarks — The species is characterized by having atranorin, a large primary thallus, and distorted podetia with a well-developed cortex.

The species is circumpolar, arctic to north temperate (Thomson 1984). In South Korea, not widespread, usually occurs in the southern part, on soil over rock.

Representative specimens (of 11) examined — **SOUTH KOREA**. **Jeonnam Prov.**, Mt. Jiri, 35°15′59.2″N 127°34′40.7″E, alt. 530 m, Hur 040227; 35°19′40.9″N 127°44′15.0″E, alt. 1564 m, Hur 060687. Mt. Dalma, 34°22′45.4″N 126°35′13.6″E, alt. 445 m, Hur 050355. **Jeju Prov.**, Mt. Halla, 33°21′18.8″N 126°30′00.4″E, alt. 1492 m, Hur 080778.

41. *Cladonia uncialis* (L.) F.H. Wigg.

Remarks — Some specimens from Japan are reported to contain hypothamnolic acid (Yoshimura 1974) and squamatic acid is reported in material from America (Thomson 1984), but neither chemotype is found in Korean specimens. *C. uncialis* is unique in having yellowish and dichotomously branched podetia and forming dense tufts. Quite similar to *C. amaurocraea*, *C. uncialis* differs in having usually smaller podetia and usnic acid and lacking cups and no barbatic acid.

The species is widespread, circumpolar, and arctic to temperate (Ahti 2000). Rare in South Korea, only one specimen has been found from Gyeongnam province, growing on soil.

Specimen examined — **SOUTH KOREA**. **Gyeongnam Prov.**, Mt. Gaya, 35°49′11.3″N 128°07′18.2″E, alt. 1440 m, Hur 040220.

Acknowledgments

The authors are grateful to Dr László Lőkös (Botanical Department of the Hungarian Natural History Museum) and Dr. Hiroshi Harada (Natural History Museum & Institute, Chiba, Japan) for reviewing the manuscript and providing valuable comments. This work was supported by a grant from The Korea National Research Resource Center Program (Grant 2010-0000660) and Korean Forest Service Program (KNA 2010) through Korea National Arboretum.

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